

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF MINES HELIUM ACTIVITY HELIUM RESEARCH CENTER INTERNAL REPORT

TESTS ON THE STATISTICAL METHOD OF TREATING THE 0° C HELIUM

DATA OBTAINED FROM A BURNETT COMPRESSIBILITY APPARATUS

BY

-	В.	J.	Dal	ton		
	19.15				-	

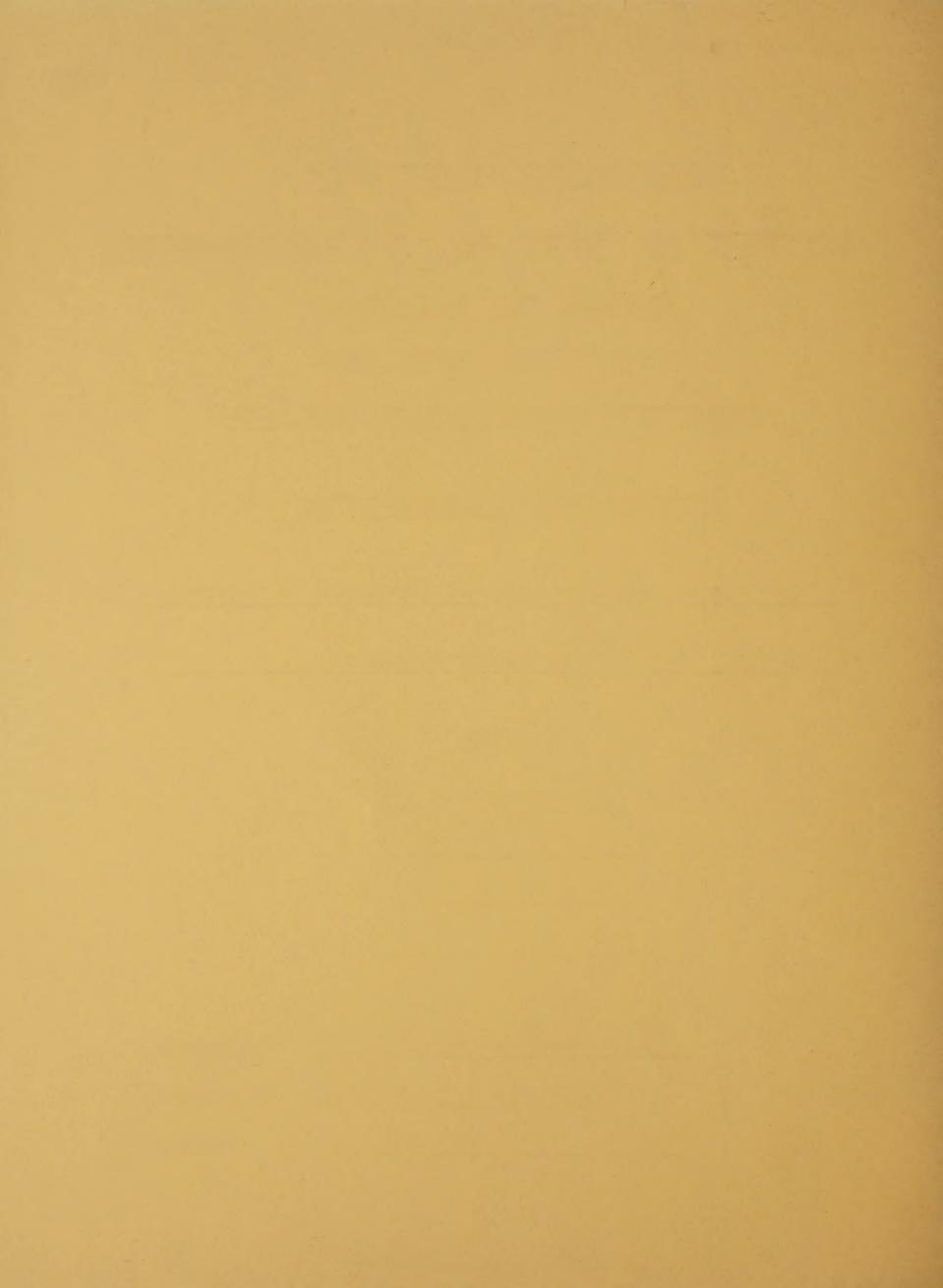
BRANCH Fundamental Research

PROJECT NO. 4335

DATE May 1966

HD 9660 .H43 M56 no.95

AMARILLO, TEXAS



Report No. 95 M56

HELIUM RESEARCH CENTER

INTERNAL REPORT

TESTS ON THE STATISTICAL METHOD OF TREATING THE 0° C HELIUM DATA OBTAINED FROM A BURNETT COMPRESSIBILITY APPARATUS

Ву

B. J. Dalton

Branch of Fundamental Research

Project 4335

May 1966

BLM Library Denver Federal Center Bldg. 50, OC-521 P.O. Box 25047 Denver, CO 80225

CONTENTS

	Page
Abstract	. 4
Introduction ,	. 5
The effect an error in the determination of α and β produces in Z, B, C, and N	. 7
The effect an error in the fractional change in the effective area of the piston (at 25° C, P=0) with pressure produces in Z, B, C, and N	. 22
The effect an error of ignoring the change in the volume ratio with pressure produces in Z, B, C, and N	. 34
References	. 39
TABLES	
1. Original experimental observations on helium at 0°C for run number 3 as reported by Briggs (5)	. 8
2. Results of the analysis of the data of table 1 for α and β defined by equations (3) and (4)	. 10
3. Compressibility factors for helium at 0° C as a function of pressure, evaluated from equation (2) and the B and C values of table 2	. 11
4. Results of the analysis of the data of table 1 assuming errors in α and β of $\pm 10\%$ and $\pm 20\%$. 13
5. Compressibility factors for helium at 0° C evaluated from the B and C values of table 4 and equation (2)	. 17

BENTHOD

222

0.5

24

11

13.1340

When I had no work to the wife

agned Central and Color of the Color of the

ar seathers on the state of the state of

SETELL

to believe and I recommended the second began began in

I along the even with the administration will be extracted by them (II) and trapped on beaution B. Sec. of and

According to a server of the contract of the c

While her hole to 5 bits o of every police of

compressibility for our not not followed or called

		Page
6.	Experimental pressures, in standard atmosphere units, as evaluated from equation (5), assuming the fractional change in the effective area of the piston (at 25° C, P=0) with pressure to	
	be in error ±10% and ±20%	24
7.	Results of the analysis of the data of table 6 for α and β defined by equations (3) and (4)	25
8.	Compressibility factors for helium at 0° C evaluated from the data of table 7 and equation (2)	29
9.	Results of the analysis of the data of table 1, assuming the volume ratio to be independent of the pressure $(\alpha = 0 = \beta)$	36
10.	Compressibility factors for helium at 0° C evaluated from the data of table 9 and equation (2)	37

TESTS ON THE STATISTICAL METHOD OF TREATING THE 0° C HELIUM DATA OBTAINED FROM A BURNETT COMPRESSIBILITY APPARATUS

by

B. J. Dalton $\frac{1}{2}$

ABSTRACT

This report describes tests on the statistical method of treating the 0° C helium data obtained from the Helium Research Center's Burnett compressibility apparatus. Tests have been carried out to show: 1. the effect an error in the determination of the pressure distortion corrections of the high-pressure bombs produces in the compressibility factor, Z, which is a function of virial coefficients, and in the value of the volume ratio at zero pressure, N; 2. the effect an error in the fractional change in the effective area of the piston (at 25° C, P=0) with pressure induces in Z and N; and 3. the effect an error of ignoring the change in volume of the containers with pressure produces in Z and N. The statistical tests are given for the compressibility factor isotherm expressed in terms of the Berlin expansion in powers of the pressure, assuming the contribution of fourth and higher virials to be negligible.

^{1/} Research chemist, Helium Research Center, Bureau of Mines, Amarillo, Texas.

Work on manuscript completed May 1966.

DATA OF THE STATISTICAL METHOD OF THEFTEN THE O'C HELICH

1511

Montred . L. M

TORRESERV

The report describes represented between the statistical method of tractions and the fit of better district from the states are the fit of bean extered out to these states are tract in the distributant of the presents distributed the effect of the theorem of the presents distributed the effect of the theorem of the produces in the compressibility interestions of the the the volume ratio at sero presents. No 1. the effect on error in the tractional change in the effective area of the picture of the volume ratio at sero presents. No 1. the picture (at 25 C. PRO) with presents induces in 2 and No and 3, the with presents presents in 2 and No and 3. the with presents presents in 2 and E. The religious of the contribution for the samplession is unwers if the presents, desiming the contribution of fourth and higher virials to be present, desiming the contribution of fourth and higher virials to be present, desiming the contribution

West of the state of the state

Nork on manuscript completed May 1966.

INTRODUCTION

Compressibility data obtained by the Burnett method involve:

1. calculating pressures from a series of experimental observations of gage temperatures, gage pressures, barometer readings, barometer temperatures, and relative humidity values; 2. determining corrections for the pressure distortion of the high-pressure containers; and 3. evaluating the parameters appearing in the expression for the compressibility of the gas and also to evaluate, simultaneously, the volume ratio at zero pressure, N.

The general expression for the Burnett experiment is of the form

$$Z_{r} = (Z_{o}/P_{o}) f_{r} N^{r} P_{r}$$
 (1)

where Z_r is the compressibility factor of the gas at pressure P_r and Z_o is the corresponding value at pressure P_o ; N is the ratio of the volumes of both containers at zero pressure to that of the first container at zero pressure; r is the expansion number; P_r is the equilibrium pressure after the $r = \frac{th}{r}$ expansion; P_o is the initial pressure;

$$f_{r} = \frac{(1+\alpha P_{1}) (1+\alpha P_{2}) ... (1+\alpha P_{r})}{(1+\beta P_{0}) (1+\beta P_{1}) ... (1+\beta P_{r-1})};$$

 α is the pressure coefficient of the volume of both containers; and β is the pressure coefficient of the volume of the first container. The pressures are expressed in either psia or standard atmosphere units and are calculated by the method previously outlined (7), $\frac{2}{}$

^{2/} Underlined numbers in parentheses refer to items in the list of references at the end of this report.

INTERNATION OF THE PARTY.

and the first posts of the second second

Control of the state of the sta

the remarkable and the party of it was a bridge of the second of the sec

to seed and not make it within monthly and at appear in the constitution of the consti

which is based on a general program developed for this particular purpose (5).

In this report, we assume Z_r is a function of the second and third virial coefficients and is expressible in terms of a Berlin expansion in powers of P_r ,

$$Z_{r} = 1 + BP_{r} + CP_{r}^{2}$$
 (2)

For the interested reader, a more detailed discussion of the case where Z_r is of some other functional form than that given by equation (2) or where Z_r is an explicit function of the molal density, ρ_r , in which case Z_r is to be considered an implicit function of P_r , is given in (2).

 f_r of equation (1) is a function of all of the observed pressures but is completely independent of the pressure distortion coefficients of the bombs which have been previously determined. The principles connected with the evaluation of α and β have been given by Briggs (5) and, therefore, will not be repeated in this report.

Statistical tests were carried out on the experimental compressibility data on helium at 0° C for run number 3 obtained by Briggs (5) in order to illustrate: 1. the effect an error in the determination of the distortion coefficients of the high-pressure containers with pressure produces in the compressibility factor, Z, which is a function of B and C, and in the volume ratio at zero pressure, N; 2. the effect an error in the fractional change in the effective area of the piston (at 25° C, P=0) with pressure introduces in Z and N; and 3. the effect an error of ignoring the pressure distortion of the bombs induces in Z and N.

which is howed on a denotal property developed for this particular part

bells but seems of the contract of the seems of a seems of the seems o

For the interested reader, a more detailed sincinsten of the case where

\$\frac{1}{2} is of some orang functional from that thus given by equation (2) or

where \$\frac{1}{2}\$ is an explicit function of the motal devaits, \$\frac{1}{2}\$, in which

case \$\frac{1}{2}\$ is an explicit function of the motal devaits, \$\frac{1}{2}\$, in which

\$\frac{1}{2}\$ of squarkon (1) is a function of \$\frac{1}{2}\$, the ubschool programes

\$\frac{1}{2}\$ of squarkon (1) is a function of all of the ubschool programes

\$\frac{1}{2}\$ of squarkon (1) is a function of all of the ubschool programes

of the bonds which have nown proviously described. The principles of the bonds which the restricted of the principles of the connected with the restricted of a total places are given by brings (5) and, therefore, will not be remired to this report.

office of the service of the effect of the contract of the description of the order of the order

The parameters of equation (1), assuming Z_r to be expressible by equation (2), were evaluated by the method outlined in (2), which is based on the general non-linear least squares problem developed for this particular problem (1, 3, 4, 8). The calculations and results of the statistical tests on the experimental PVT data for helium at 0° C for run number 3 reported in (5) are given in the following sections.

THE EFFECT AN ERROR IN THE DETERMINATION OF α AND β PRODUCES IN Z, B, C, AND N

The experimental results of Briggs (5) compressibility measurements on helium at 0° C for run number 3 are given in table 1 of this report. The values of column 1 are expansion numbers corresponding to the observed pressures of column 2. The pressures are in standard atmosphere units and the number after the letter E merely indicates the power of 10 by which each pressure is multiplied.

Equation (1),

$$Z_{r} = (Z_{o}/P_{o}) f_{r} N^{r} P_{r}, \qquad (1)$$

was applied to the data of table 1 assuming \mathbf{Z}_{r} to be of the form as given by equation (2),

$$Z_r = 1 + BP_r + CP_r^2$$
 (2)

The values of the pressure distortion coefficients of the highpressure bombs were taken to be (5, 6):

$$\alpha (0^{\circ} C) = 1.6678 \times 10^{-6} \text{ atm}^{-1},$$
 (3)

$$\beta (0^{\circ} C) = 1.6671 \times 10^{-6} \text{ atm}^{-1}$$
 (4)

The parameters of on a parameter of the parameter of the

E COLA SE NO POLICIARIZATIVO NES DE PORREZ NA VERSON SON

The experimental results of Aragon (3) comprehently denounce of the money of the money of the money of the second of the second

Squarios ill.

(1) (1) 1, 1 1, 2 (1) 1, - 3

the appliced to the date of lable I serious E, to be of the form to

(2)

The values of the pressure distortion coefficients of the high-

(a) - 1 6671 × 10 6 atm - (3 '0) '8

TABLE 1.-Original experimental observations on helium at 0° C for run number 3 as reported by Briggs (5)

$$Z_r = (Z_o/P_o) f_r N^r P_r, P_r \text{ in atm}$$
 $Z_r = 1 + BP_r + CP_r^2$
 $\alpha = 1.6678 \times 10^{-6} \text{ atm}^{-1}$
 $\beta = 1.6671 \times 10^{-6} \text{ atm}^{-1}$
 $b^{1/} = -3.50 \times 10^{-8} \text{ in}^2/\text{in}^2 \text{ psi}$

r	Pr(obs)			
0	7.0128236E02			
1	3.0170799E02			
2	1.4061376E02			
3	6.8033559E01			
4	3.3517320E01			
5	1.6660572E01			
6	8.3186011E00			
7	4.1639855E00			

1/ b is the fractional change in the effective area of the piston (at 25° C, P=0) with pressure. This value was supplied by the Ruska Instrument Corporation; see (5) and (7) for a more detailed discussion of this constant.

ANLE 1 -Original experiences of entering an helica at 00 C for two

man na , a , , a , a , a (, a / 2) = +p

1- no B- no a system a se

"- mrs d-01 x 1700.1 - 8

Jag William For incre - Va

1.012831602 2.01012831602 2.010129350202 2.01023553203 4.335122003 5.35603522003 6.368512000

b is the transional change in the effective arms of the platon (as 25°C, E=0) with pressure this value was supplied by the Ruska instrument Corporation see (5) and (2) for a more detailed discussion of this constant

The three parameters of equation (1), B, C, and N, were evaluated by an iteration technique ($\underline{2}$) to give the results reported in table 2 of this report, assuming α and β to be defined by equations (3) and (4), respectively. The values of column 1 of this table are expansion numbers corresponding to the observed pressures of column 2. The pressures of column 3 are those pressures which exactly satisfy equation (1). Column 4 is the residual of $P_{r(obs)}$ and is just the difference of columns 2 and 3. The relative error of the observed pressure, column 5, is just column 4 divided by column 2.

The best estimates of the unknown parameters of equation (1) are also included in table 2 along with the best estimate of the uncertainty of each of these quantities. The best values for B, C, and N were taken to be the least squares values, where the observed pressures were taken to be of equal reliability. The quantities S_N , S_B , and S_C are the calculated standard errors of N, B, and C evaluated by the method outlined in (8). The quantities given under the heading VARIANCES AND COVARIANCES are just variances and covariances of the parameters calculated by the method outlined in (8) (i.e., S2N is the variance of N; S2BC is the covariance of BC; etc.).

From the data of table 2 and equation (2), the compressibility factors of table 3 were calculated, together with the standard deviation of each Z. The values of column 1 of this table are nominal pressures in standard atmosphere units. Column 2 gives values of Z corresponding to the pressures of column 1, while the standard deviations of these compressibility factors, SZ, are given in column 3.

The three concentration of the colored of the colored of the section of the colored of the color

The less entered to take the column processes of equation (I) are sent to testinate the column of the entered o

The presence of rebile 2 and equation (2), the conquestion of the state of deviation of the state of rebiles 2 and color with the state of deviation of the state of the state

TABLE 2.-Results of the analysis of the data of table 1 for α and β defined by equations (3) and (4)

				P,OBSP,CAL.
r	P,OBS.,ATM.	P, CAL., ATM.	P,OBSP,CAL.	P,OBS.
				52
0	7.0128236E&02	7.0128236E&02	0.0000E-99	0.0000E-99
1	3.0170799E&02	3.0170849E&02	-4-99133E-04	-1.65435E-06
2	1.4061376E&02	1.4061112E&02	2.64039E-03	1.87776E-05
3	6.8033559E&01	6.8037124E&01	-3.56490E-03	-5.23991E-05
4	3.3517320E&01	3.3518813E&01	-1.49289E-03	-4.45411E-05
5	1.6660572E&01	1.6659332E&01	1.23916E-03	7.43771E-05
6	8.3186011E-00	8.3161327E-00	2.46844E-03	2.96737E-04
7	4.1639855E-00	4.1603444E-00	3.64111E-03	8.74430E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30445E-05

CONSTANTS AND STANDARD ERRORS

N 1.994559047E-00	SN 1.29990E-04
B 5.277062588E-04	SB 8.84365E-07
C -4.739061450E-08	SC 5.96411E-10

S2N	1.68975E-08
S2B	7.82102E-13
SZC	3.55707E-19
S2BC	-5.22569E-16
S2BN	-1.10699E-10
S2CN	7.13077E-14

TABLE 2. - Magnifus of the most yets of the days of table 1 for 2 and 5 defined by aquations (3) and (4)

	P.OBS. VATH.	
	, 500388558510-T	

SUM OF WEIGHTED SQUERES OF THE RESIDUALS 4.304436-05

CONSTANTS AND STANDARD ERRORS

TABLE 3.-Compressibility factors for helium at 0°C as a function of pressure, evaluated from equation (2) and the B and C values of table 2

PRESSURE, ATM.	cleal size correled out	SZ
1.000E-00	1.0005276588E-00	1.05758E-06
2.000E-00	1.0010552229E-00	2.04752E-06
5.000E-00	1.0026373465E-00	4-89493E-06
1.000E&01	1.0052723235E-00	9.44892E-06
2.500E&01	1.0131630373E-00	2.24701E-05
5.000E&01	1.0262668364E-00	4.30866E-05
7.500E&01	1.0393113972E-00	6.28415E-05
1.000E&02	1.0522967197E-00	8.19129E-05
1.250E&02	1.0652228039E-00	1.00365E-04
1.500E&02	1.0780896499E-00	1.18224E-04
2.000E&02	1.1036456271E-00	1.52167E-04
2.500E&02	1.1289646512E-00	1.83675E-04
3.000E&02	1.1540467223E-00	2.12614E-04
3.500E&02	1.1788918403E-00	2.38822E-04
4.000E&02	1.2035000052E-00	2.62127E-04
4.500E&02	1.2278712170E-00	2.82357E-04
5.000E&02	1.2520054757E-00	2.99346E-04
6.000E&02	1.2995631340E-00	3.22985E-04
7.000E&02	1.3461729800E-00	3.31965E-04
8.000E&02	1.3918350137E-00	3.25547E-04
9.000E&02	1.4365492351E-00	3.03584E-04
1.000E&03	1.4803156442E-00	2.67134E-04

results given to gable 4, the compressibility factors of gable 5 core

best S and the (3) nelsessed from the best of the base of the base

Now suppose the determinations of the pressure distortion coefficients of the high-pressure containers are in error - this is not to imply or be construed to mean that α and β are incorrect! However, to illustrate the first statistical test carried out on the 0° C helium data for run number 3, we assume these quantities to be in error by some amount. Then on solving equation (1), we would get new values for B, C, and N as well as new values of Z. The problem, therefore, is to reevaluate these parameters and compressibility factors and to decide whether the effect an error in α and β produces a statistically significant difference in the values of B, C, N, and Z.

Let us assume errors in α and β of $\pm 10\%$ and $\pm 20\%$:

$$0.8 \alpha = 1.33424 \times 10^{-6} \text{ atm}^{-1}, \quad 0.8 \beta = 1.33368 \times 10^{-6} \text{ atm}^{-1};$$

 $0.9 \alpha = 1.50102 \times 10^{-6} \text{ atm}^{-1}, \quad 0.9 \beta = 1.50039 \times 10^{-6} \text{ atm}^{-1};$
 $1.1 \alpha = 1.83458 \times 10^{-6} \text{ atm}^{-1}, \quad 1.1 \beta = 1.83381 \times 10^{-6} \text{ atm}^{-1};$
 $1.2 \alpha = 2.00136 \times 10^{-6} \text{ atm}^{-1}, \quad 1.2 \beta = 2.00052 \times 10^{-6} \text{ atm}^{-1}.$

Table 4 of this report gives the results of the new values of the parameters assuming errors in α and in β of $\pm 10\%$ and $\pm 20\%$. The values given in table 4 have the same meaning as those of table 2. From the results given in table 4, the compressibility factors of table 5 were calculated, together with the uncertainty of each Z factor.

From the data given in tables 1, 2, 3, 4, and 5 of this report, the following significant results indicate that:

1. Even if the determination of the pressure distortion coefficients of the bombs is in error by as much as $\pm 20\%$, the least squares

Now suppose the determinations of the pressure discortion coefficients of the high-pressure containers are in error - this is not to imply or be construed to mean that o and is are incorract! Newwer, to fillustrate the first statistical cost carried out on the O' C helium data for two number 1, we assume those quantities to be in error by some smound. Then on solving equation (i), we would get now values for B. C. and N as well as now values of Z. The problem, therefore, is to neevaluate those parameters and compressibility factors and to decide whether the effect an error in a and compressibility factors and to decide whether the effect an error in a and forduces a starterically significant difference in the values of B. C. N. and R.

Let us assisse errors to 8 hou S of 107 and 2007;

0.8 d = 1.33524 x 10 aca , 0.8 5 = 1.33358 x 10 aca ;

1. to - 1.53458 x 10 0 0 1.1 f = 1.63331 x 10 0 01.1

1.3 c = 2.00036 x 10 0 am - 1.2 8 = 2.00042 x 10 am - 1.

Table 4 of this report gives the results of the new values of the parameters assuming errors in a and in 3 of :10% and :20%. The values given in table 4 have the same meaning as those of factor 2. From the results given in table 4, the compressibility factors of table 5 were calculated, tagether with the uncertainty of each 2 factor.

Prom the data given in tables 1, 7, 4, and 5 of this report, the following significant results indicate that:

1. Even if the determination of the pressure distortion coefficients of the bombs is intercor by as much as 190%, the least squares

TABLE 4.-Results of the analysis of the data of table 1 assuming errors in α and β of $\pm 10\%$ and $\pm 20\%$

 $0.8\alpha = 1.33424 \times 10^{-6} \text{ atm}^{-1}$ $0.8\beta = 1.33368 \times 10^{-6} \text{ atm}^{-1}$

r	P,OBS.,ATM.	P,CAL.,ATM.	P,OBSP,CAL.	P,OBSP,CAL. P,OBS.
0	7.0128236E&02	7.0128236E&02	0.00000E-99	0.00000E-99
1	3.0170799E&02	3.0170849E&02	-4.99511E-04	-1.65561E-06
2	1.4061376E&02	1.4061112E&02	2.64261E-03	1.87934E-05
3	6.8033559E&01	6.8037128E&01	-3.56832E-03	-5.24494E-05
4	3.3517320E&01	3.3518814E&01	-1.49367E-03	-4.45641E-05
5	1.6660572E&01	1.6659331E&01	1.24067E-03	7.44677E-05
6	8.3186011E-00	8.3161305E-00	2.47058E-03	2.96995E-04
7	4.1639855E-00	4.1603425E-00	3.64300E-03	8.74884E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.31114E-05

CONSTANTS AND STANDARD ERRORS

N 1.994559505E-00	SN	1.30086E-04
B 5.273648758E-04	SB	8.84952E-07
C -4.754640934E-08	SC	5.96924E-10

SZN	1.69224E-08
S2B	7.83141E-13
S2C	3.56319E-19
S2BC	-5.23370E-16
S2BN	-1.10854E-10
SZCN	7-14232F-14

na contract and number 1 become by what our in structure will be delineral a 21000

" OF THE PARTY I - 184 O THE "TOTAL ASSET I - 187 U

	t .	
	T. OIZBERGE	

BUR DE WEIGHTED SQUARES OF THE RESIDUALS "4. STELLE-US

CONSTANTS AND STANDARD ERRORS

VERLIANDERS AND DEVARIANCES

90-145500-1 M50 100-14500-13 91-301902-14 100001-1-100001-10 100001-1-100001-10

TABLE 4.-Results of the analysis of the data of table 1 assuming errors in α and β of $\pm 10\%$ and $\pm 20\%$ (Con.)

 $0.9\alpha = 1.50102 \times 10^{-6} \text{ atm}^{-1}$ $0.9\beta = 1.50039 \times 10^{-6} \text{ atm}^{-1}$

				P.OBSP.CAL.
r	P.OBS., ATM.	P, CAL., ATM.	P,OBSP,CAL.	P,OBS.
0	7 01202245502	7.0128236E&02	0.00000E-99	0.00000E-99
0	7.0128236E&02	3.0170849E&02	-4.99322E-04	-1.65498E-06
1	3.0170799E&02	The second secon	2.64150E-03	1.87855E-05
2	1.4061376E&02	1.4061112E&02		
3	6.8033559E&01	6.8037126E&01	-3.56661E-03	-5.24243E-05
4	3.3517320E&01	3.3518813E&01	-1.49328E-03	-4.45526E-05
5	1.6660572E&01	1.6659332E&01	1.23992E-03	7.44224E-05
6	8.3186011E-00	8.3161316E-00	2.46951E-03	2.96866E-04
7	4.1639855E-00	4.1603434E-00	3.64206E-03	8.74657E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30780E-05

CONSTANTS AND STANDARD ERRORS

N 1.994559276E-00	SN	1.30038E-04
B 5.275355672E-04	SB	8.84659E-07
C -4.746851200E-08	SC	5.96668E-10

SZN	1.69100E-08
S2B	7.82621E-13
SZC	3.56013E-19
S2BC	-5.22969E-16
S2BN	-1.10777E-10
S2CN	7.13654E-14

of every princes and the same and to provide any to prince and

The Total of state of - el. D.

0.50 - 1. SOLOZ x 10 - br.0

	CHTREE-Ships 4	ANTAL EXPOSE

SUM OF HELDHTED SQUARES OF THE ANGROSIS A STREET OF HUZ

CONSTANTS AND STRANBARD EXACTS

TABLE 4.-Results of the analysis of the data of table 1 assuming errors in α and β of $\pm 10\%$ and $\pm 20\%$ (Con.)

 $1.1\alpha = 1.83458 \times 10^{-6} \text{ atm}^{-1}$ $1.1\beta = 1.83381 \times 10^{-6} \text{ atm}^{-1}$

r	P,OBS.,ATM.	P,CAL.,ATM.	P,OBSP,CAL.	P,OBSP,CAL.
0	7.0128236E&02	7.0128236E&02	0.00000E-99	0.00000E-99
1	3.0170799E802	3.0170849E&02	-4.98944E-04	-1.65373E-06
2	1.4061376EE02	1.4061112E&02	2.63928E-03	1.87697E-05
3	6.8033559E&01	6.8037123E&01	-3.56319E-03	-5.23740E-05
4	3.3517320E&01	3.3518812E&01	-1.49251E-03	-4.45296E-05
5	1.6660572E&01	1.6659333E&01	1.23841E-03	7.43318E-05
6	8.3186011E-00	8.3161337E-00	2.46737E-03	2.96608E-04
7	4.1639855E-00	4.1603453E-00	3.64016E-03	8.74202E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30111E-05

CONSTANTS AND STANDARD ERRORS

N	1.994558817E-00	SN	1.29942E-04
B	5.278769505E-04	SE	8.84071E-07
C	-4.731271686E-08	SC	5.96155E-10

SZN	1.68850E-08
S2B	7.81583E-13
S2C	3.55401E-19
S2BC	-5.22169E-16
S2BN	-1.10622E-10
SZCN	7-12500F-14

AL WALLS INTRODUCED I SINCE IN RIGHT DOWN THE PARTY OF TH

Total Total Street 1 - Street Total Total Street St

LADIS - CROSS		1	
580.4			
	riorzessantanz		
		00-34686847*	

SUM OF WELCHIEF SULARES OF THE RESIDUALS 4. SOLUTE-OS

CAMPBELLIA AND STRAIGHTD ENGINES

STREET AND DIVARIANCES

TABLE 4.-Results of the analysis of the data of table 1 assuming errors in α and β of $\pm 10\%$ and $\pm 20\%$ (Con.)

 $1.2\alpha = 2.00136 \times 10^{-6} \text{ atm}^{-1}$ $1.2\beta = 2.00052 \times 10^{-6} \text{ atm}^{-1}$

r	P.OBS., ATM. P.CAL., ATM	M. P,OBSP,CAL.	P,OBSP,CAL. P,OBS.
0 1 2 3 4 5 6	7.0128236E&02 7.0128236E& 3.0170799E&02 3.0170849E& 1.4061376E&02 1.4061112E& 6.8033559E&01 6.8037121E& 3.3517320E&01 3.3518812E& 1.6660572E&01 1.6659334E& 8.3186011E-00 8.3161348E-	0.00000E-99 0.02 -4.98754E-04 0.02 2.63817E-03 0.01 -3.56148E-03 0.01 -1.49212E-03 0.01 1.23765E-03	0.00000E-99 -1.65310E-06 1.87618E-05 -5.23489E-05 -4.45181E-05 7.42865E-05 2.96479E-04
7	4.1639855E-00 4.1603463E-		8.73975E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.29777E-05

CONSTANTS AND STANDARD ERRORS

N 1.994558588E-00	SN	1.29894E-04
B 5.280476424E-04	SB	8.83778E-07
C -4.723481905E-08	SC	5.95898E-10

SZN	1.68726E-08
S2B	7.81063E-13
S2C	3.55095E-19
S2BC	-5.21769E-16
S2BN	-1.10544E-10
S2CN	7.11924E-14

nt secret principal A of Out to wish out to starting only in extract of MISAT

THE "TOL & SOCIALS = 85. 1

" non " 91 x selso 1 = e5 1

		1	
	and Annalisan A		
			16.8

SUM OF HELGHIED SOURCES OF THE RESIDUALS VERSIONS

CONSTANTS AND STANDARD EMADERS

N 1.4945645-00 SN 1.198945-00 N 5.296945-01 N 5.286916-01 N 5.286916-01

VARIABLES AND COVARIANCES

528 7.310036-13 528 7.310036-13 528 -1.550056-14 528 -1.550056-19 528 7.1102856-10

TABLE 5.-Compressibility factors for helium at 0° C evaluated from the B and C values of table 4 and equation (2)

 $0.8\alpha = 1.33424 \times 10^{-6} \text{ atm}^{-1}$ $0.8\beta = 1.33368 \times 10^{-6} \text{ atm}^{-1}$

PRESSURE, ATM.	Z	SZ
1.000E-00	1.0005273173E-00	1.05818E-06
2.000E-00	1.0010545395E-00	2.04872E-06
5.000E-00	1.0026356357E-00	4.89791E-06
1.000EE01	1.0052688941E-00	9.45481E-06
2.500E&01	1.0131544053E-00	2.24846E-05
5.000E&01	1.0262493777E-00	4.31147E-05
7.500E&01	1.0392849171E-00	6.28827E-05
1.000E&02	1.0522610234E-00	8.19665E-05
1.250E&02	1.0651776968E-00	1.00431E-04
1.500E&02	1.0780349371E-00	1.18301E-04
2.000E&02	1.1035711187E-00	1.52264E-04
2.500E&02	1.1288695683E-00	1.83790E-04
3.000E&02	1.1539302859E-00	2.12744E-04
3.500E&02	1.1787532713E-00	2.38965E-04
4.000E&02	1.2033385248E-00	2.62280E-04
4.500E&02	1.2276860462E-00	2.82518E-04
5.000E&02	1.2517958355E-00	2.99512E-04
6.000E&02	1.2993022181E-00	3.23153E-04
7.000E&02	1.3458576724E-00	3.32126E-04
8.000E&02	1.3914621986E-00	3.25693E-04
9.000E&02	1.4361157966E-00	3.03709E-04
1.000E803	1.4798184664E-00	2.67233E-04

most because of the molecule and demand of the surface of the surf

" THE O DI P ROSEL I - 58 0 1" ATE O DI S ASSES I - 68 0

TABLE 5.-Compressibility factors for helium at 0° C evaluated from the B and C values of table 4 and equation (2) (Con.)

 $0.9\alpha = 1.50102 \times 10^{-6} \text{ atm}^{-1}$ $0.9\beta = 1.50039 \times 10^{-6} \text{ atm}^{-1}$

PRESSURE, ATM.	Z	SZ
1.000E-00	1.0005274880E-00	1.05788E-06
2.000E-00	1.0010548812E-00	2.04812E-06
5.000E-00	1.0026364911E-00	4.89642E-06
1.000E&01	1.0052706088E-00	9.45187E-06
2.500E&01	1.0131587213E-00	2.24774E-05
5.000E&01	1.0262581070E-00	4.31006E-05
7.500E&01	1.0392981571E-00	6.28621E-05
1.000E&02	1.0522788716E-00	8.19397E-05
1.250E&02	1.0652002504E-00	1.00398E-04
1.500E&02	1.0780622935E-00	1.18262E-04
2.000E&02	1.1036083729E-00	1.52215E-04
2.500E&02	1.1289171098E-00	1.83732E-04
3.000E&02	1.1539885040E-00	2.12679E-04
3.500E&02	1.1788225558E-00	2.38894E-04
4.000E&02	1.2034192649E-00	2.62204E-04
4.500E&02	1.2277786315E-00	2.82437E-04
5.000E&02	1.2519006556E-00	2.99429E-04
6.000E&02	1.2994326760E-00	3.23069E-04
7-000E&02	1.3460153261E-00	3.32045E-04
8.000E&02	1.3916486060E-00	3.25620E-04
9.000E&02	1.4363325157E-00	3.03647E-04
1.000E&03	1.4800670552E-00	2.67183E-04

The late of the second second

" min " DT = 10000 L = 50.0 " DEN " DE N 5010E L = 100.0

S THIN - SHORZSHIP

2.0000E-00 2.0000E-00 2.0000E801 2.0000E801 2.0000E801 2.0000E802 2.0000E802 2.0000E802 3.0000E802 4.0000E802 4.0000E802 5.0000E802 5.0000E802 5.0000E802 6.0000E802 6.0000E802 7.0000E802 7.0000E802 7.0000E802

TABLE 5.-Compressibility factors for helium at 0° C evaluated from the B and C values of table 4 and equation (2) (Con.)

 $1.1\alpha = 1.83458 \times 10^{-6} \text{ atm}^{-1}$ $1.1\beta = 1.83381 \times 10^{-6} \text{ atm}^{-1}$

PRESSURE, ATM.	Z *	SZ
1.000E-00	1.0005278296E-00	1.05728E-06
2.000E-00	1.0010555646E-00	2.04692E-06
5.000E-00	1.0026382019E-00	4.89345E-06
1.000EE01	1.0052740382E-00	9.44598E-06
2.500E&01	1.0131673533E-00	2.24629E-05
5.000E&01	1.0262755657E-00	4.30725E-05
7.500EE01	1.0393246372E-00	6.28209E-05
1.000E&02	1.0523145678E-00	8-18861E-05
1.250E&02	1.0652453576E-00	1.00333E-04
1.500E&02	1.0781170064E-00	1.18186E-04
2.000E&02	1.1036828814E-00	1.52118E-04
2.500E&02	1.1290121928E-00	1.83618E-04
3.000E&02	1.1541049406E-00	2.12549E-04
3.500E&02	1.1789611248E-00	2.38751E-04
4.000E&02	1.2035807455E-00	2.62051E-04
4.500E&02	1.2279638025E-00	2.82277E-04
5.000E&02	1.2521102960E-00	2.99264E-04
6.000EE02	1.2996935922E-00	3.22901E-04
7.000E&02	1.3463306341E-00	3.31884E-04
8.000E&02	1.3920214216E-00	3.25474E-04
9.000E&02	1.4367659548E-00	3.03522E-04
1.000EE03	1.4805642336E-00	2.67084E-04

01

ANTE PARENTANA I TIL PRINCIPLE DEL REGIONAL MARINES DE REGION CAMBO

Part Part I series you as I - Proper Train to the series of the last

PRESSURE, MIN.

TABLE 5.-Compressibility factors for helium at 0° C evaluated from the B and C values of table 4 and equation (2) (Con.)

 $1.2\beta = 2.00052 \times 10^{-6} \text{ atm}^{-1}$ $1.2\alpha = 2.00136 \times 10^{-6} \text{ atm}^{-1}$

PRESSURE, ATM.	estuciosZ for the avenue	SZ
1.000E-00	1.0005280004E-00	1.05698E-06
2.000E-00	1.0010559063E-00	2.04632E-06
5.000E-00	1.0026390573E-00	4.89196E-06
1.000E&01	1.0052757529E-00	9.44303E-06
2.500E&01	1.0131716692E-00	2.24557E-05
5.000E&01	1.0262842950E-00	4.30584E-05
7.500E&01	1.0393378773E-00	6.28003E-05
1.000E&02	1.0523324160E-00	8.18593E-05
1.250E&02	1.0652679112E-00	1.00300E-04
1.500E&02	1.0781443629E-00	1.18148E-04
2.000E&02	1.1037201357E-00	1.52070E-04
2.500E&02	1.1290597344E-00	1.83560E-04
3.000E&02	1.1541631590E-00	2.12484E-04
3.500E&02	1.1790304095E-00	2.38679E-04
4.000E&02	1.2036614859E-00	2.61974E-04
4.500E&02	1.2280563882E-00	2.82197E-04
5.000E&02	1.2522151164E-00	2.99181E-04
6.000E&02	1.2998240506E-00	3.22817E-04
7.000E&02	1.3464882883E-00	3.31804E-04
8.000EE02	1.3922078297E-00	3°25401E-04
9.000E&02	1.4369826747E-00	3.03459E-04
1.000EE03	1.4808128234E-00	2.67034E-04

mort barealeve of the section rate section and the section of the

1- may 4 01 2, 50000 2 = 55.1 1 2 1 2 1 1000 2 = 85.1

PRESSURE, ATH.

solution for the volume ratio at zero pressure, N, is not significantly affected. We conclude, therefore, that errors of as much as $\pm 20\%$ in the determination of α and β produce insignificant differences in the least squares solution of N.

- 2. The least squares solutions for the second and third virial coefficients, B and C, assuming errors of as much as $\pm 20\%$ in the pressure distortion coefficients, differ from those evaluated for $1.0~\alpha$ = $1.6678 \times 10^{-6}~atm^{-1}$ and $1.0~\beta$ = $1.6671 \times 10^{-6}~atm^{-1}$ by less than the uncertainty with which we know these quantities. This is interpreted to mean that a $\pm 20\%$ error in the determination of the pressure distortion coefficients of the bombs produces differences in the least squares solutions of B and of C which are statistically insignificant.
- 3. The values of the compressibility factor differ by no more than the stated deviations of these Z's for the five solutions: 0.8 α ; 0.9 α ; 1.0 α ; 1.1 α ; 1.2 α . We conclude, therefore, that errors of this magnitude in α and β produce differences in Z which are no greater than the calculated uncertainties with which we know these quantities.

One of the important points to come out of this analysis, which I had not appreciated before, is that the independently determined values of the pressure distortion coefficients of the bombs apparently have little influence on the precision of the PVT data obtained from a Burnett compressibility apparatus. This means, therefore, that any error in the determination of α and β should not significantly influence the <u>internal</u> precision of compressibility measurements on

Rollerton for the volume tatio or core pressure, N. Is not alguiranting of the determinantian of a und a produce that errors of se systematic on the determinantian of a und a produce instghiliteant differences in the least equator and of a produce of the determinantian of N.

confinence, a and C, exemple, errors of as much as 120% in the pres-

them constitutions of the boxte produces differences in the laws squares wolfitiens of f which ere exarts steely the ignificant,

In the stated deviations of these 2's for the rive columns 0.8 of this magnification of the rive columns of this magnification of and the constitute, therefore, then extents of this magnification in a and the procuse differences in a which are on the greater than the columns undertained undertained with which we know these quantities.

Use of the important patent to one out of the inalysis, which i has not appreciated before, is that the independently autorained values of the present distortion coefficients of the bombs apperantly have little influence on the presistent of the SVF data obtained, from a Surnett coeperatibility apparatus. This means, therefore, that may error in the determination of a and 5 should not significantly influence the internal precision of a and 5 should not significantly

the gas. This has been found to be true in the analysis of the 0° C helium isotherm data of Briggs (5) for run number 3.

THE EFFECT AN ERROR IN THE FRACTIONAL CHANGE IN THE EFFECTIVE AREA OF THE PISTON (AT 25° C, P=0) WITH PRESSURE PRODUCES IN Z, B, C, AND N

To illustrate better the second statistical test applied to the experimental results reported in $(\underline{5})$, the expression from which pressures are calculated (7) is introduced:

$$P_{g} = \frac{M_{a} (1 - \rho_{a}/\rho_{b}) g_{L}/g_{S}}{A_{o} (1 + bP_{g})[1 + c(t-25)]},$$
 (5)

where

 $P_g = \text{calculated gage pressure } (\underline{5}, \underline{7}), \text{ psig},$

M = apparent mass, as determined by comparison with brass
 standards, in air, 1b,

 ρ_{a} = density of air, g/cc,

 ρ_b = density of brass, g/cc,

g_T = local acceleration due to gravity, gal,

g_S = standard acceleration due to gravity, gal,

A = effective area of piston (at 25° C, P=0), in^2 ,

b = fractional change in A_0 with pressure, in^2/in^2 psi,

c = temperature coefficient of linear expansion of the piston-cylinder combination, in/in °C, and

t = temperature of the piston-cylinder, °C.

the gas. This has been found to be true in the miliety of the G C his limit is the first of the G C his limit is the first of the first

THE CHILD AND THE SET OF THE SET

To illustrate britar the second stalleries cost applied to the separation of the second staller passion of the second staller passion of the second second staller passion of the second second

THE PARTY OF THE P

Wilco

isted ([[] supersug ages betainfes = [5

desired file continuous of benished by composition with briefs

of the or . Drobnote.

cole and or valends - To

poly amend to estamb. = jo

ing resident out the local security, get .

R. - srandavid-ecceleration due to gravity, gel,

A - wiferctive order of warren (see 25° C. Pett), in ..

the freinfame change for a with presented and the pair.

eds to notemper result to in tollines our enquest " a

practical cylinder constantion, to/to 'C, and

T - samper that of the placement today, "O.

Suppose the value of b is in error by some amount. Then the pressures as calculated from equation (5) would be different and, hence, we would get new values for B, C, and N as well as new values for the compressibility factor. The problem is to determine the effect an error in b produces in the volume ratio at zero pressure, the virial coefficients, and the compressibility factor and to decide whether this error is statistically significant.

Let us assume the fractional change in the effective area of the piston (at 25° C, P=0) with pressure to be in error $\pm 10\%$ and $\pm 20\%$:

0.8 b =
$$-2.80 \times 10^{-8} \text{ psi}^{-1}$$
;
0.9 b = $-3.15 \times 10^{-8} \text{ psi}^{-1}$;
1.1 b = $-3.85 \times 10^{-8} \text{ psi}^{-1}$;
1.2 b = $-4.20 \times 10^{-8} \text{ psi}^{-1}$.

Table 6 of this report gives the new values for the pressures as determined from the solution of equation (5) using the method outlined in $(\underline{5})$ and $(\underline{7})$. All pressures are expressed in standard atmosphere units. The values of column 1 of this table are expansion numbers corresponding to the observed pressures of columns 2, 3, 4, and 5.

Equation (1) was applied to the data of table 6, assuming Z_r to be expressible by equation (2). Table 7 of this report gives the results of the analysis of the data of table 6 for α and β defined by equations (3) and (4), where the quantities given in this table have the same meaning as those of table 2. From the values of B and C of table 7, the compressibility factors of table 8 were calculated.

Suppose the value of b is in error by some ensure. Then the properties as calculated from equation (5) would be different and, hence, we would get new values for D. C. and N as well as new values for the comprehendibility factor. The problem is to determine the effect an error of produces in the volume ratio at zero pressure, the virtel coefficients, and the compressibility factor and to decide whether this error of examples in the compressibility factor and to decide whether this error

Let us assume the fractional change in the affective grea of the pieres (at 25° C, P=C) with pressure to be in error with and with

1-1eg 8-01 x 08.5- - d 8.0

1-1eg 8-01 x 28.5- - d 8.0

1-1eg 8-01 x 28.5- - d 1.1

lubic 5 of this report gives one new values for the pressures as determined from the appution of equation (5) using the method cutifued in (5) and (7). All pressures are expressed in standard standard standard standard standard standard standard standard standard corresponding to the observed pressures of columns 2, 3, 4, and 5.

he expressible by equation (2). Table 7 of this report gives the results of the analysis of the dual to the cools 6 for a and 8 delined by equations (1) and (0), where the quantities gives in this table have the same meaning as those of table 2. From the values of 8 and C of table 7, the temperalibility factors of table 8 were calculated.

TABLE 6.-Experimental pressures, in standard atmosphere units, as evaluated from equation (5), assuming the fractional change in the effective area of the piston (at 25° C, P=0) to be in error ±10% and ±20%

	_P <u>1</u> /	p <u>2</u> /	<u>3</u> /	P 4/
r	r(obs)	r(obs)	r(obs)	r(obs)
0	7.0123187E02	7.0125711E02	7.0130761E02	7.0133287E02
1	3.0169868E02	3.0170334E02	3.0171265E02	3.0171731E02
2	1.4061175E02	1.4061276E02	1.4061477E02	1.4061577E02
3	6.8033095E01	6.8033327E01	6.8033791E01	6.8034023E01
4	3.3517210E01	3.3517265E01	3.3517375E01	3.3517429E01
5	1.6660546E01	1.6660559E01	1.6660584E01	1.6660597E01
6	8.3185954E00	8.3185983E00	8.3186040E00	8.3186068E00
7	4.1639844E00	4.1639849E00	4.1639860E00	4.1639866E00

^{1/} Pressures as calculated by the method outlined in (5) and (7), assuming b to be in error by -20%.

^{2/} Pressures as calculated by the method outlined in (5) and (7), assuming b to be in error by -10%.

^{3/} Pressures as calculated by the method outlined in (5) and (7), assuming b to be in error by +10%.

^{4/} Pressures as calculated by the method outlined in (5) and (7), assuming b to be in error by +20%.

TABLE & - Constinuental presentes, in standard atmosphere saits, as evalue to the company of the tractional change in the company of the comp

	TE LEGISTA	(ana) 7
	7.0123711802 3.0170339202 1.4061176802 3.3817269801 1.5660539801 8.3185983800	

[] Pressures as ostculated by the method outlined in (5) and (2), assuming b to me in arror by -20%.

2) Freedomes as calculated by the method outlined in (5) and (2),

2/ Pressures as calculated by the method marifood in (5) and (2),

4/ Iressures as cellulated by the method outstand in (5) and (1), sessuring b to be in error by +20%.

TABLE 7.-Results of the analysis of the data of table 6 for α and β defined by equations (3) and (4)

$$0.8b = -2.80 \times 10^{-8} \text{ psi}^{-1}$$

r	P,OBS.,ATM.	P,CAL.,ATM.	P,OBSP,CAL.	P,OBSP,CAL.
0	7.0123187E&02	7.0123187E&02	0.00000E-99	0.00000E-99
1	3.0169868E&02	3.0169918E&02	-4.99031E-04	-1.65407E-06
2	1.4061175E&02	1.4060911E&02	2.63970E-03	1.87729E-05
3	6.8033095E&01	6.8036659E&01	-3.56376E-03	-5.23828E-05
4	3.3517210E&01	3.3518703E&01	-1.49266E-03	-4.45341E-05
5	1.6660546E&01	1.6659307E&01	1.23865E-03	7.43466E-05
6	8.3185954E-00	8.3161277E-00	2.46771E-03	2.96651E-04
7	4.1639844E-00	4.1603439E-00	3.64045E-03	8.74273E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30223E-05

CONSTANTS AND STANDARD ERRORS

N	1.994558905E-00	SN	1.29960E-04
В	5.276058057E-04	SB	8.84184E-07
C	-4.739691916E-08	SC	5.96346E-10

S2N	1.68896E-08
S2B	7.81781E-13
S2C	3.55628E-19
S2BC	-5.22405E-16
S2BN	-1.10651E-10
S2CN	7-12832F-14

harries a long of the department to one of the part and the strange and the st

D. O. C. 10 . 10 . C = 10.0

	,		
		4 JUNESBRANE-00	

SUM OR METCHTED SQUARES OF THE RESIDUALS GATHERES

CONSTANTS AND STANDARD ERRORS

VARIANCES AND COUNTRANCES

TABLE 7.-Results of the analysis of the data of table 6 for α and β defined by equations (3) and (4) (Con.)

$$0.9b = -3.15 \times 10^{-8} \text{ psi}^{-1}$$

r	P,OBS.,ATM.	P,CAL.,ATM.	P,OBSP,CAL.	P,OBSP,CAL. P,OBS.
0	7.0125711E&02	7.0125711E&02	0.00000E-99	0.00000E-99
1	3.0170334E&02	3.0170383E&02	-4.99082E-04	-1.65421E-06
2	1.4061276E&02	1.4061012E&02	2.64005E-03	1.87753E-05
3	6.8033327E&01	6.8036892E&01	-3.56433E-03	-5.23910E-05
4	3.3517265E&01	3.3518758E&01	-1.49277E-03	-4.45376E-05
5	1.6660559E&01	1.6659320E&01	1.23891E-03	7.43619E-05
6	8.3185983E-00	8.3161302E-00	2.46808E-03	2.96694E-04
7	4.1639849E-00	4.1603441E-00	3.64078E-03	8.74351E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30334E-05

CONSTANTS AND STANDARD ERRORS

N 1.994558976E-00	SN 1.29975E-04
B 5.276560323E-04	SB 8.84274E-07
C -4.739376953E-08	SC 5.96378E-10

S2N	1.68936E-08
S2B	7.81942E-13
S2C	3.55667E-19
S2BC	-5.22487E-16
S2BN	-1.10675E-10
S2CN	7-12955E-14

boutlet & bus A not digitar to make not to alevisor off to attain the stains of which

THE BUTTON OF THE OWNER OF THE

CARTA S281143			
	. EU-STREDALL -		

SUM OF MELCHEN SULARES OF THE RESIDUALS ASSESSED.

SUCCESSION OF STREET OF STREET

36-5:		

TABLE 7.-Results of the analysis of the data of table 6 for α and β defined by equations (3) and (4) (Con.)

$$1.1b = -3.85 \times 10^{-8} \text{ psi}^{-1}$$

				P,OBSP,CAL.
r	P.OBS., ATM.	P, CAL., ATM.	P, DBSP, CAL.	P,OBS.
0	7.0130761E&02	7.0130761E&02	0.00000E-99	0.00000E-99
1	3.0171265E&02	3.0171315E&02	-4.99183E-04	-1.65450E-06
2	1.4061477E&02	1.4061213E&02	2.64074E-03	1.87799E-05
3	6.8033791E&01	6.8037357EE01	-3.56547E-03	-5.24073E-05
4	3.3517375E&01	3.3518868E&01	-1.49301E-03	-4.45446E-05
5	1.6660584E&01	1.6659345E&01	1.23942E-03	7.43923E-05
6	8.3186040E-00	8.3161352E-00	2.46880E-03	2.96781E-04
7	4.1639860E-00	4.1603446E-00	3.64144E-03	8.74508E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30556E-05

CONSTANTS AND STANDARD ERRORS

N	1.994559117E-00	SN	1.30005E-04
В	5.277564850E-04	SB	8.84456E-07
C -	-4.738745396E-08	SC	5.96444E-10

S2N	1.69015E-08
S2B	7.82262E-13
S2C	3.55746E-19
S2BC	-5.22652E-16
S2BN	-1.10724E-10
SZCN	7-13200F-14

TABLE 7. - Magniles of the onelysis of the data to archive the non a deliment by equations (1) and (4) (Con)

" Jan 2" OI N 25 Fr = dL I

•		

SUM DE BETCHTED SOURRES OF THE RESTHANDS GENEROL-ON

CONSTANTS AND STANDARD LARBES

350		

TABLE 7.-Results of the analysis of the data of table 6 for α and β defined by equations (3) and (4) (Con.)

$$1.2b = -4.20 \times 10^{-8} \text{ psi}^{-1}$$

r	P,OBS.,ATM.	P,CAL.,ATM.	P,OBSP,CAL.	P,OBSP,CAL. P,OBS.
0	7.0133287E&02	7.0133287E&02	0.00000E-99	0.00000E-99
1	3.0171731E&02	3.0171780E&02	-4.99234E-04	-1.65464E-06
2	1.4061577E&02	1.4061313E&02	2.64109E-03	1.87823E-05
3	6.8034023E&01	6.8037589E&01	-3.56604E-03	-5.24155E-05
4	3.3517429E&01	3.3518923E&01	-1.49313E-03	-4.45481E-05
5	1.6660597E&01	1.6659357E&01	1.23967E-03	7.44075E-05
6	8.3186068E-00	8.3161377E-00	2.46916E-03	2.96824E-04
7	4.1639866E-00	4.1603448E-00	3.64176E-03	8.74586E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30667E-05

CONSTANTS AND STANDARD ERRORS

N 1.994559188E-00	SN 1.30021E-04
B 5.278067112E-04	SB 8.84546E-07
C -4.738428794E-08	SC 5.96477E-10

SZN	1.69054E-08
S2B	7.82423E-13
S2C	3.55785E-19
SZBC	-5.22734E-16
S2BN	-1.10748E-10
S2CN	7.13323E-14

MBLE 7 .- Results of the analysis of the days of table 5 for 2 ded 3 daying by aquations (3) and (A) (Con.)

1- ten 8-01 k US A- = di.1

		P.OBS.,ATM.	
	0.8037909EE01 1.6659357EE01 0.3161317E-00		

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.30657E-05

CONSTANTS AND STANDARD ERRORS

TABLE 8.-Compressibility factors for helium at 0° C evaluated from the data of table 7 and equation (2)

 $0.8b = -2.80 \times 10^{-8} \text{ psi}^{-1}$

PRESSURE, ATM.	Z	SZ
1.000E-00	1.0005275584E-00	1.05732E-06
2.000E-00	1.0010550220E-00	2.04704E-06
5.000E-00	1.0026368441E-00	4.89381E-06
1.000E&01	1.0052713183E-00	9.44682E-06
2.500E&01	1.0131605220E-00	2.24653E-05
5.000E&01	1.0262617979E-00	4.30775E-05
7.500E&01	1.0393038277E-00	6.28283E-05
1.000E&02	1.0522866113E-00	8.18957E-05
1.250E&02	1.0652101488E-00	1.00344E-04
1.500E&02	1.0780744401E-00	1.18199E-04
2.000E&02	1.1036252843E-00	1.52134E-04
2.500E&02	1.1289391439E-00	1.83634E-04
3.000E&02	1.1540160190E-00	2.12566E-04
3.500E&02	1.1788559094E-00	2.38766E-04
4.000E&02	1.2034588152E-00	2.62064E-04
4.500E&02	1.2278247364E-00	2.82287E-04
5.000E&02	1.2519536730E-00	2.99270E-04
6.000E&02	1.2995005925E-00	3.22897E-04
7.000E&02	1.3460995736E-00	3.31867E-04
8.000E&02	1.3917506163E-00	3.25443E-04
9.000E&02	1.4364537206E-00	3.03477E-04
1.000E&03	1.4802088865E-00	2.67028E-04

ment between the contract of the selfent to the contract of th

Lang Ball to TRUE - W AH.O,

PRESSURE ATA:

1.000E-00
2.000E-00
2.000EE01
2.000EE02
1.000EE02
1.000EE02
2.000EE02
2.000EE02
2.000EE02
2.000EE02
2.000EE02
3.000EE02
4.000EE02
4.000EE02

TABLE 8.-Compressibility factors for helium at 0° C evaluated from the data of table 7 and equation (2) (Con.)

$$0.9b = -3.15 \times 10^{-8} \text{ psi}^{-1}$$

Z	SZ
1.0005276086E-00	1.05745E-06
1.0010551224E-00	2.04728E-06
1.0026370953E-00	4.89437E-06
1.0052718209E-00	9.44787E-06
1.0131617797E-00	2.24677E-05
1.0262643171E-00	4.30820E-05
1.0393076124E-00	6.28349E-05
1.0522916655E-00	8.19043E-05
1.0652164763E-00	1.00355E-04
1.0780820450E-00	1.18211E-04
1.1036354556E-00	1.52150E-04
1.1289518974E-00	1.83655E-04
1.1540313704E-00	2.12590E-04
1.1788738745E-00	2.38794E-04
1.2034794098E-00	2.62096E-04
1.2278479762E-00	2.82322E-04
1.2519795737E-00	2.99308E-04
1.2995318623E-00	3.22941E-04
1.3461362755E-00	3.31916E-04
1.3917928133E-00	3.25495E-04
1.4365014757E-00	3.03530E-04
1.4802622627E-00	2.67081E-04
	1.0005276086E-00 1.0010551224E-00 1.0026370953E-00 1.0052718209E-00 1.0131617797E-00 1.0262643171E-00 1.0393076124E-00 1.0522916655E-00 1.0652164763E-00 1.0780820450E-00 1.1289518974E-00 1.1289518974E-00 1.1788738745E-00 1.1788738745E-00 1.2278479762E-00 1.2278479762E-00 1.2519795737E-00 1.2995318623E-00 1.3461362755E-00 1.3917928133E-00 1.4365014757E-00

TARKE 8 -Compressibility factors for melion at 0 T evaluation from

1- Jeg 8-01 x 81.6- + 38.0 x

20-318954-9		
	09-98818887108-1	

TABLE 8.-Compressibility factors for helium at 0° C evaluated from the data of table 7 and equation (2) (Con.)

 $1.1b = -3.85 \times 10^{-8} \text{ psi}^{-1}$

PRESSURE, ATM.	Z	SZ
1.000E-00	1.0005277090E-00	1.05771E-06
2.000E-00	1.0010553234E-00	2.04777E-06
5.000E-00	1.0026375977E-00	4.89549E-06
1.000E&01	1.0052728261E-00	9.44997E-06
2.500E&01	1.0131642949E-00	2.24726E-05
5.000E&01	1.0262693556E-00	4.30911E-05
7.500E&01	1.0393151819E-00	6.28481E-05
1.000E&02	1.0523017739E-00	8.19215E-05
1.250E&02	1.0652291316E-00	1.00376E-04
1.500E&02	1.0780972550E-00	1.18237E-04
2.000E&02	1.1036557988E-00	1.52183E-04
2.500E&02	1.1289774054E-00	1.83695E-04
3.000E&02	1.1540620746E-00	2.12639E-04
3.500E&02	1.1789098066E-00	2.38850E-04
4.000E&02	1.2035206014E-00	2.62159E-04
4.500E&02	1.2278944588E-00	2.82392E-04
5.000E&02	1.2520313 7 90E-00	2.99385E-04
6.000E&02	1.2995944076E-00	3.23030E-04
7.000E&02	1.3462096871E-00	3.32014E-04
8.000E&02	1.3918772175E-00	3.25599E-04
9.000E&02	1.4365969988E-00	3.03638E-04
1.000E&03	1.4803690311E-00	2.67187E-04

and between the solden and solden

Tara Bros - City Commence of

Opposition and a second	
00-10978-1801/08-1	
OO-SSTOMAROPRELL	
no-jinenesemert	

TABLE 8.-Compressibility factors for helium at 0° C evaluated from the data of table 7 and equation (2) (Con.)

$$1.2b = -4.20 \times 10^{-8} \text{ psi}^{-1}$$

PRESSURE, ATM.	Z	SZ
1.000E-00	1.0005277593E-00	1.05784E-06
2.000E-00	1.0010554238E-00	2.04801E-06
5.000E-00	1.0026378489E-00	4.89605E-06
1.000EE01	1.0052733286E-00	9.45102E-06
2.500E&01	1.0131655526E-00	2.24750E-05
5.000E&01	1.0262718748E-00	4.30957E-05
7.500E&01	1.0393189667E-00	6.28547E-05
1.000E&02	1.0523068282E-00	8.19301E-05
1.250E&02	1.0652354594E-00	1.00387E-04
1.500E&02	1.0781048602E-00	1.18249E-04
2.000E&02	1.1036659707E-00	1.52200E-04
2.500E&02	1.1289901598E-00	1.83716E-04
3.000E&02	1.1540774274E-00	2.12663E-04
3.500E&02	1.1789277736E-00	2.38878E-04
4.000E&02	1.2035411984E-00	2.62190E-04
4.500E&02	1.2279177017E-00	2.82427E-04
5.000E&02	1.2520572836E-00	2.99423E-04
6.000E&02	1.2996256830E-00	3.23074E-04
7.000E&02	1.3462463967E-00	3.32063E-04
8.000E&02	1.3919194247E-00	3.25652E-04
9.000E&02	1.4366447668E-00	3.03692E-04
1.000E&03	1.4804224232E-00	2.67240E-04

TABLE 8 .- Compressibility tactors for helding at 0° C statuares from

1-100 8-01 x 05 x = x d5 1 /

	0.0-3060-5
1-14835777356-00	

From the results given in tables 1, 2, 3, 6, 7, and 8, the following significant results indicate that:

- 1. The least squares solution for the volume ratio at zero pressure, N, is not affected by errors of $\pm 10\%$ or $\pm 20\%$ in the fractional change of the effective area of the piston (at 25° C, P=0) with pressure. This was taken to mean that errors in b of as much as $\pm 20\%$ do not significantly influence the least squares value of the volume ratio at zero pressure.
- 2. The least squares solutions for B, assuming $\pm 10\%$ errors in b, differ from the second virial coefficient evaluated for b = -3.5 x 10^{-8} in $^2/\text{in}^2$ psi by about 1/17 the calculated uncertainty of this parameter; the corresponding differences for $\pm 20\%$ errors in b are about 9 times smaller than the uncertainty of B. This means, therefore, that errors of as much as $\pm 20\%$ in the value of the fractional change in the effective area of the piston (at 25° C, P=0) with pressure influences the least squares value of the second virial coefficient of the gas an insignificant amount.
- 3. The least squares solutions for the third virial coefficient, assuming errors of 0.8 b and 1.2 b, differ from C evaluated for 1.0 b by about 1/100 the calculated uncertainty of the third virial coefficient! The corresponding differences, assuming errors of 0.9 b and 1.1 b, are (1/200 S_C). This is interpreted to mean that errors in the value of b of as much as $\pm 20\%$ produce insignificant differences in the least squares solution of C, the third virial coefficient of the gas.

.

From the results given in tables 1, 2, 5, 6, 7, and 8, the following significant results indicate that:

- In The least equates adjution for the volume ratio at zero presented by errors of siOt or 120% in the franctional charge of the effective area of the places (at 25°C. 7+0) with pressors. This was taken to seem that arrors in b of as much as 120% do not 16- mificantly influence the least aquates value of the volume ratio at zero pressure.
 - 2. The least squares solutions for 3. assuming till errors to b, differ from the second virial conflictent evaluated for b = -3.5 x 10⁻⁸ in /in pel by about 1/17 the calculated uncertainty of this permanent; the corresponding differences for 270% errors in b are about 9 times shaller then the uncertainty of 8. This means, therefore, that errors of as much as 270% in the value of the fractional change in the effective area of the platon (at 25° C, P=0) with pressure influences the least squares value of the second virial cosificient of the gen an insignificant amount.
 - 3. The least squares solutions for the third virial coefficient, assuming errors of 0.8 b and 1.2 b. differ from C evaluated for 1.0 b by about 1/100 the calculated uncertainty of the third virial coefficient! The corresponding differences, assuming errors of 0.9 b and 1.1 b, are (1/200 S_p). This is interpreted to mean that errors in the value of b of as such as 120% produce insignificant differences in the least squares solution of C, the third virial coefficient of the

4. The values of Z, assuming 0.8 b and 1.2 b, differ from Z evaluated for 1.0 b by about (1/5 S_Z) over the pressure range 1 to 700 atmospheres; the corresponding differences, assuming 0.9 b and 1.1 b, are almost an order of magnitude smaller than the uncertainty of the compressibility factor over this same pressure range. We conclude, therefore, that errors as great as 0.8 b and 1.2 b produce differences in Z which are no greater than 1/5 the uncertainty with which we know these compressibility factors over the pressure range of this experiment.

We also note that the independently determined value of the fractional change in the effective area of the piston (at 25°C, P=0) with pressure, b, has no significant influence on the precision of the PVT data or on N. This means, therefore, that <u>any</u> error in the determination of b should not affect the internal precision of compressibility measurements on the gas or the value of the zero pressure volume ratio of the Burnett apparatus. We found this to be true in the analysis of these data.

THE EFFECT AN ERROR OF IGNORING THE CHANGE IN THE VOLUME RATIO WITH PRESSURE PRODUCES IN Z, B, C, AND N

The final test applied to the experimental compressibility measurements of table 1 was to determine the effect an error of ignoring the pressure distortion of the bombs produces in the compressibility factor, the virial coefficients, and the zero pressure volume ratio and then to decide whether this assumption of $\alpha = \beta = 0$ differs significantly from the results previously calculated using the present values for these

The values of I, securing 0.8 h and 1.2 b, allier from E evaluated for 1.0 t by about (2/5 \$2) over the pressure range 1 to 700 stude pheres; the corresponding differences, assuming 0.9 b and 1.1 b, are almost an order of magnitude smaller than the uncertainty of the compressibility factor over this same pressure range. We conclude, there fore, that orrors as great as 0.8 k and 1.2 b produce differences in I which are no greater than 1/5 the uncertainty with thick we know these compressibility factors over the pressure range of this experiment.

We also note that the independently derivatively of the fractional change in the effective area of the paston far 25" 0, P=0) with
presents, b, has no significant influence on the process of the PVI
dete or on Mr. One weens, therefore, that may error in the detertiontion of b should not affect the forestell precision of completellity
measurements on the gas of the value of the rero presente volume rario
of the Surmett apparence. We round this to be true in the stallyris of
these data.

IN THE VOLUME RANTO WITH PRESSURE PRODUCES IN Z. B. C. AND N

The final rest applied to the experimental congressibility measuresents of twole I was to descrutine the effect an error of ignoring the

pressure distortion of the bomes produces to the cuspress(hillow factor.

The virial coefficients, and the zero pressure volume volume than in

decide whether this assumption of despend of the pressure volume in these in

pressure distortion coefficients (i.e., $\alpha = 1.6678 \times 10^{-6} \text{ atm}^{-1}$, $\beta = 1.6671 \times 10^{-6} \text{ atm}^{-1}$).

Equation (1) was applied to the data of table 1, where Z_r is expressible by equation (2), to give the results of table 9 for α = β = 0. The values given in table 9 have the same meaning as those of table 2. From the results of table 9 and equation (2), the compressibility factors of table 10 were calculated. The deviations, S_Z , given in this table are standard deviations as determined by the method previously given in (8).

The results of tables 1, 2, 3, 9, and 10 indicate the following:

- 1. The least squares solution for N, assuming α = β = 0, differs from that evaluated for α = 1.6678 x 10⁻⁶ atm⁻¹ and β = 1.6671 x 10⁻⁶ atm⁻¹ by (1/100 S_N). This was interpreted to mean that ignoring the pressure distortion coefficients of the bombs does not produce a statistically significant difference in the least squares solution for the zero pressure volume ratio.
- 2. The solution for B, assuming $\alpha = \beta = 0$, differs from that previously calculated using the present values for these pressure distortion coefficients by more than one would expect from the calculated uncertainties. This suggests, therefore, that ignoring the change in the volume ratio with pressure could be significant insofar as the second virial coefficient of the gas is concerned.
- 3. The solution for C, assuming $\alpha = \beta = 0$, differs from that evaluated using the present values for these pressure distortion coefficients by no more than one would expect; that is, the difference is less

pressure distortion coefficients (i.e., o = 1.0575 m 10 mm 1, 5 = 1.6571 m 10 mm 1);

Equation (1) was applied to the date of table 1, where 2, us expressible by equation (2), to give the reculr of table 9 for or 2 m 2 m 0. The values given in table 9 have the same meditive as those of table 2. First the tesuity of table 3 and equation (3), the ountressability factors of table 10 were calculated. The deviations, 5, given in this table are similarly deviations as directorized by the period pre-

The results of tebles 1, 2, 3, 9, and 10 tostante the following:

1. The least aquates solution for 0, security o = 2 = 0, diving from their evaluated for 0 = 1,0078 × 10 0 and 8 = 1,6671 × 10 0 atm by (1/100 Sy). This was interpreted to mean their ignoring the present distortion coefficients of the bridge does not produce a statistically eignificant difference in the last squares spinstern for the deep research volume curto.

2. The solution for f, essuming a = p = 0, differs from that providesly calculated units the present values for these presents distorrigo rosifitelests by more than one hould expect from the estimited uncertainties. This sungests, therefore, that ignoring the dinner in the values ratio with pressure could be significant insufer as the second virial coefficient of the gas is concerned.

3. The solution for C. sesuning q = 8 = 0, differs from that evaluated using the pressure distinction coefficients by no more than one would espect; that is, the difference is less

TABLE 9.-Results of the analysis of table 1, assuming the volume ratio to be independent of the pressure ($\alpha = 0 = \beta$)

r	P,OBS.,ATM.	P,CAL.,ATM.	P,OBSP,CAL.	P,OBSP,CAL.
1	Paudojaino	PyCALogAino	PRODUCTERCALO	P,003.
0	7.0128236E&02	7.0128236E&02	0.00000E-99	0.00000E-99
1	3.0170799E&02	3.0170849E&02	-5.01023E-04	-1.66062E-06
2	1.4061376E&02	1.4061111E&02	2.65149E-03	1.88565E-05
3	6.8033559E&01	6.8037141EE01	-3.58199E-03	-5.26504E-05
4	3.3517320E&01	3.3518817E&01	-1.49675E-03	-4.46560E-05
5	1.6660572E&01	1.6659325E&01	1.24671E-03	7.48301E-05
6	8.3186011E-00	8.3161219E-00	2.47917E-03	2.98027E-04
7	4.1639855E-00	4.1603349E-00	3.65058E-03	8.76703E-04

SUM OF WEIGHTED SQUARES OF THE RESIDUALS 4.33797E-05

CONSTANTS AND STANDARD ERRORS

N	1.994561338E-00	SN	1.30470E-04
В	5.259993502E-04	SB	8.87300E-07
C	-4.816958247E-08	SC	5.98977E-10

VARIANCES AND COVARIANCES

S2N	1.70224E-08
S2B	7.87302E-13
S2C	3.58774E-19
S2BC	-5.26578E-16
S2BN	-1.11476E-10
S2CN	7.18860E-14

The state of the property of the state of th

40-355016 C-		
1-240716-03		

SUM OF MELENTER SOUNTES OF THE RESIDUALS. A. STROLLING TO MAZ

CONSTRUCT AND STRUCKS DEADLES

WARRENCES AND COUNTRACTOR

TABLE 10.-Compressibility factors for helium at 0° C evaluated from the data of table 9 and equation (2)

PRESSURE, ATM.	Z	SZ
1.000E-00	1.0005259511E-00	1.06059E-06
2.000E-00	1.0010518060E-00	2.05352E-06
5.000E-00	1.0026287925E-00	4.90978E-06
1.000E&01	1.0052551765E-00	9.47836E-06
2.500E&01	1.0131198777E-00	2.25423E-05
5.000E801	1.0261795435E-00	4.32272E-05
7.500E&01	1.0391789973E-00	6.30473E-05
1.000E&02	1.0521182391E-00	8.21807E-05
1.250E&02	1.0649972690E-00	1.00692E-04
1-500E&02	1.0778160869E-00	1.18607E-04
2.000E&02	1.1032730867E-00	1.52651E-04
2.500E&02	1.1284892386E-00	1.84249E-04
3.000E&02	1.1534645426E-00	2.13264E-04
3.500E&02	1.1781989987E-00	2.39535E-04
4.000E&02	1.2026926068E-00	2.62891E-04
4.500E&02	1.2269453671E-00	2.83158E-04
5.000E&02	1.2509572794E-00	3.00172E-04
6.000E&02	1.2982585604E-00	3.23823E-04
7.000E&02	1.3445964497E-00	3.32769E-04
8.000E&02	1.3899709474E-00	3.26277E-04
9.000E&02	1.4343820534E-00	3.04207E-04
1.000E&03	1.4778297677E-00	2.67628E-04

CV contraga bear a local language and annual value of the said

PRESSURE, ATM.

| 1.08052 | 1.0801856868 | 1.08058568 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.08058 | 1.0805

than the uncertainty with which we know this difference. We conclude, therefore, that ignoring the pressure distortion of N has an insignificant effect on the least squares value of C.

4. The compressibility factors of the gas calculated for zero distortion of the volume ratio with pressure differ from those evaluated using $\alpha = 1.6678 \times 10^{-6} \text{ atm}^{-1}$, $\beta = 1.6671 \times 10^{-6} \text{ atm}^{-1}$ by more than is to be expected from the calculated uncertainties. This means, therefore, that the effect of ignoring the pressure distortion coefficients of the bombs has a statistically significant effect on the values of Z which amounts to more than three times the expected difference at 700 atmospheres; about twice the expected difference at 300 atmospheres, and about 1.4 times the expected difference at 50 atmospheres.

then the uncertainty with which we know this difference. We conclude, therefore, then ignoring the presence discovered of H has an instanted cant effect on the least squares value of C.

The compressibility factors of the gest relicited for sero distortion of the volume ratio with pressure differ from these avaluated asing a = 1.6678 x 10⁻⁶ arm , b = 1.6678 x 10⁻⁶ arm the calculated uncertainties. This means, incretore, that the effect of ignoring the pressure distortion coefficients of the bombs has a scatletically eignificant effect on the values of I which smounts to goes than three that the expected difference at 100 atmospheres, and pheres; about twice the expected difference at 100 atmospheres, and about 1.4 thms the expected difference at 100 atmospheres.

REFERENCES

- Barieau, Robert E., and B. J. Dalton. Method of Solving Non-Linear Least Squares Problems. Helium Research Center Memorandum Report No. 63, March 1965, 17 pp.
- 2. ____. Method for Treating PVT Data From a Burnett Compressibility
 Apparatus. Helium Research Center Internal Report No. 86, April
 1966, 61 pp.
- 3. ____. Non-Linear Regression and the Principle of Least Squares.

 Helium Research Center Memorandum Report No. 62, March 1965, 59 pp.
- 4. _____. Non-Linear Regression and the Principle of Least Squares.

 The Method of Evaluating the Constants and the Calculation of Variances and Covariances. Helium Research Center Internal Report No.

 85, April 1966, 55 pp.
- 5. Briggs, Ted C. Compressibility Data for Helium at 0° C and Pressures to 800 Atmospheres. Helium Research Center Internal Report No. 88, April 1966, 111 pp.
- 6. _____. Elastic Distortion of the High-Pressure Compressibility Bombs

 Over the Temperature Range 0° to 80° C. Helium Research Center Internal Report No. 84, February 1966, 39 pp.
- 7. _____. Pressure Measurement With Ruska Instrument Corporation Piston Gage, Serial No. 9274. Helium Research Center Internal Report No. 65, November 1964, 22 pp.

· HEPERBUCKS

- 1. Baricou, Robert E., and A. J. Dalton. Mathed of Solving Non-Lineur
 Least Squares Problems. Neltum Research Center Memorandon Report No.
 63, Hardh 1965, 17 pp.
 - Apparatus, Weltum Resusted Center Internal Report No. So, April 1956, 61 pp.
 - 3. _____ Hon-Linear Regression and the Principle of Loast Stuntes,
 Hellum Research Center Nemorandum Acquire No. 62, March 1965, 59 pp.
 - 4. ____ Non-Linear Regression and the Principle of Seast Squares.

 The Method of Evaluating the Constants and the Cafetalation of Vertances and Covertances. Helium Research Center Internal Report No.

 85, April 1966, 55 pp.
- 5. Briggs, Ted C. Compressibility Date for Hellum at D' C and Pressures to 800 Atmospheres. Reliam Research Conter Internal Report No. 53, April 1966, 111 pp.
- 6. ____ Elastic Distortion of the High-Pressure Compressibility Bomber

 Over the Temperature Sange O' to 80° C. Hellus Research Center Internal Report No. 64, February 1989, 39 op.
 - Gaga, Sarial No. 9274. Helium Rasearch Gonfer Internal Report No. 65, November 1954, 22 pp.

REFERENCES (Con.)

8. Dalton, B. J., and Robert E. Barieau. Method of Calculating Variances and Covariances From the Fundamental Definition of These

Quantities and the Law for the Propagation of Errors. Helium

Research Center Internal Report No. 81, January 1966, 29 pp.

EXTERNOCES (Con.)

B. Dalton, B. J., and Robert E. Barleau. Method of Calculating Variances and Covariances From the Fundamental Definition of These Quantities and the Law for the Propagation of Strors. Helium Rosearch Center Internal Report No. 81, January 1966: 29 pp.



